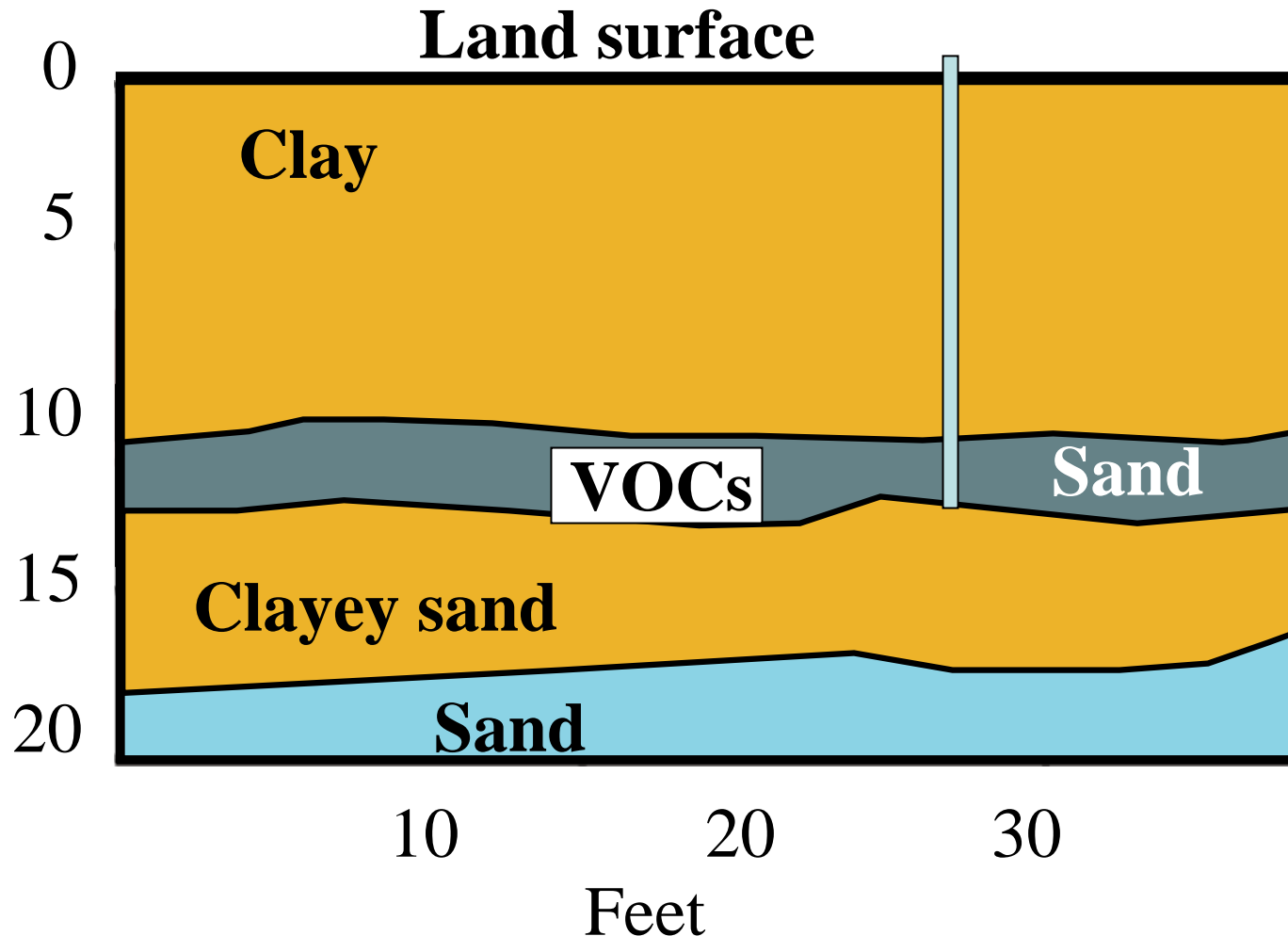


Influence of in-well dissolved-oxygen convection on well sampling

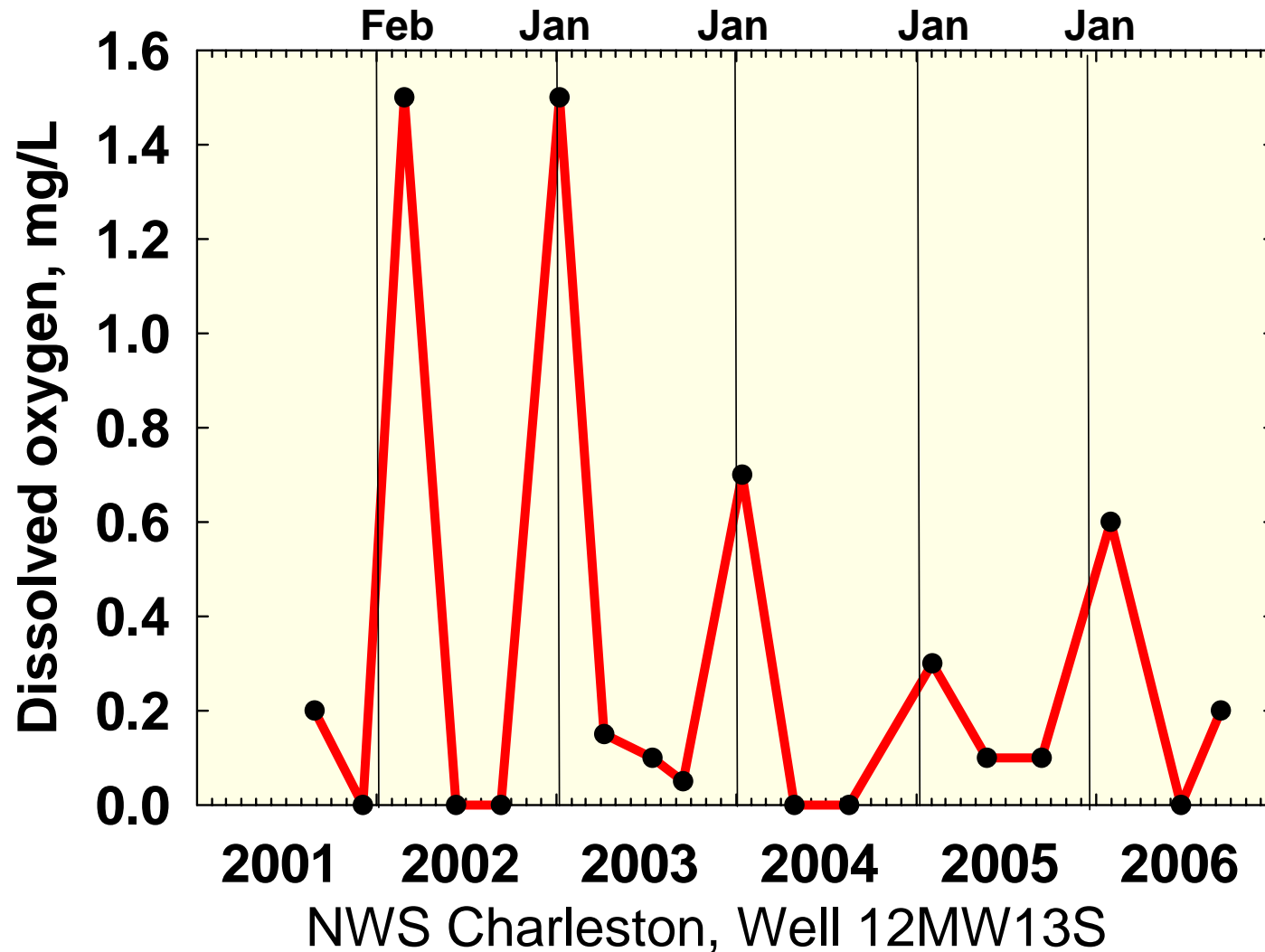
By Don A. Vroblesky
U.S. Geological Survey
Columbia, SC

NWS Charleston, SC.

About 6 to 10 ft of tight clay above the aquifer

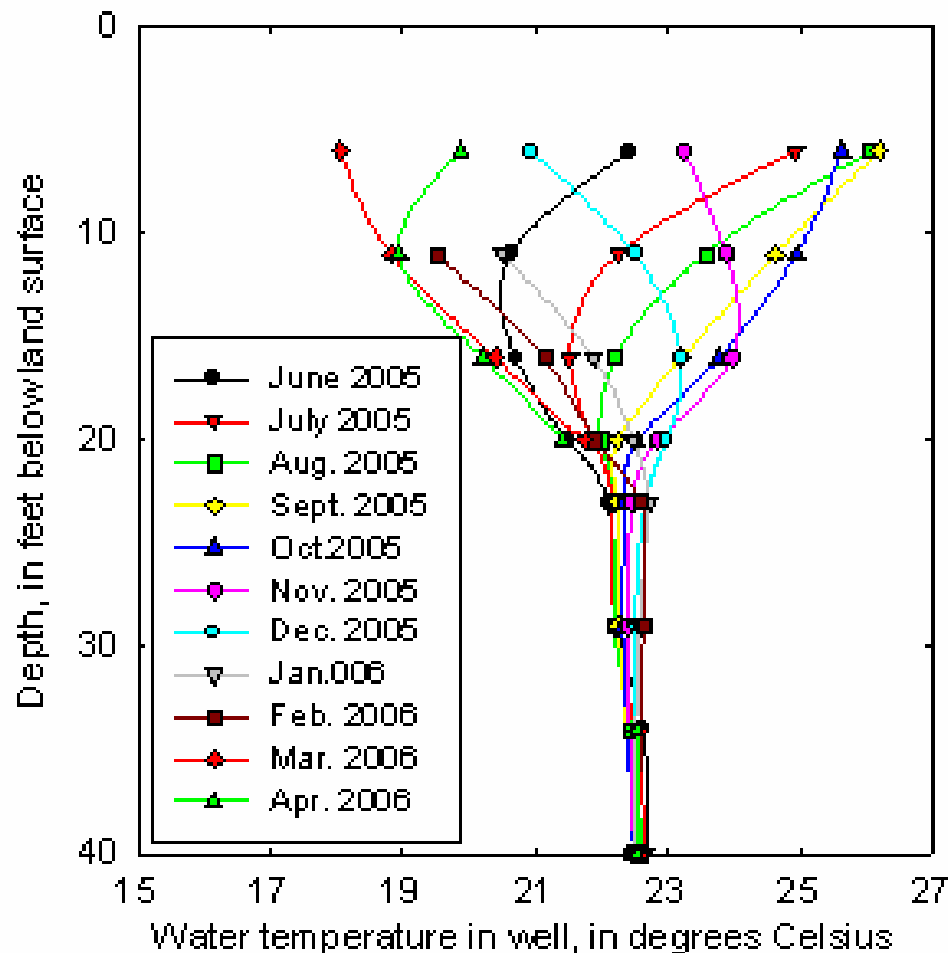


Every year in the winter, the aquifer became aerobic or became more oxidized (low-flow sampling)



Temperature profiles in wells vary seasonally

A. Water temperature profiles



Parris Island

South
Carolina

2005-2006

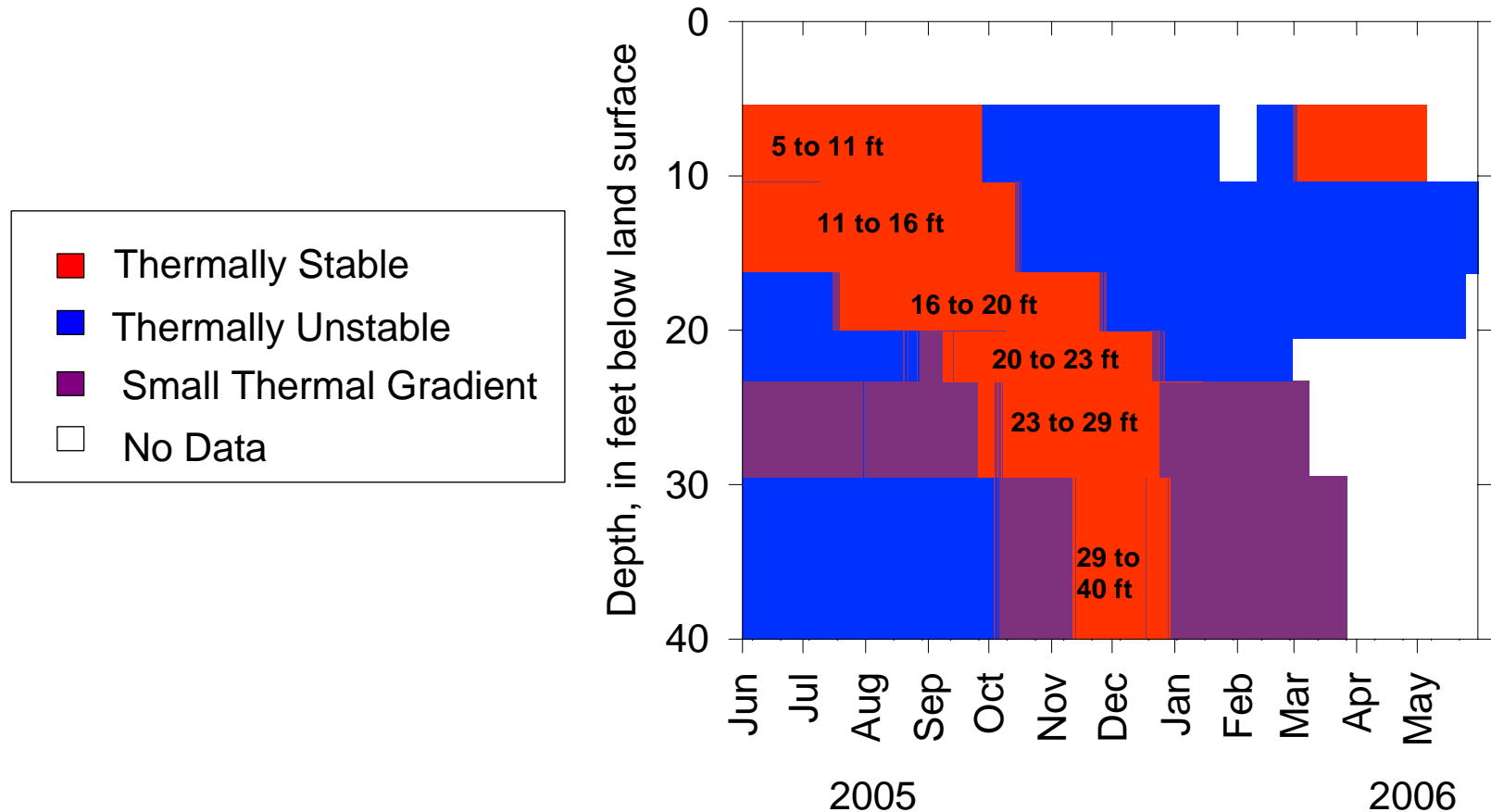
Convection cells can develop in wells



Cool water

Warm water

Temperature profiles and depths of convection zones change seasonally



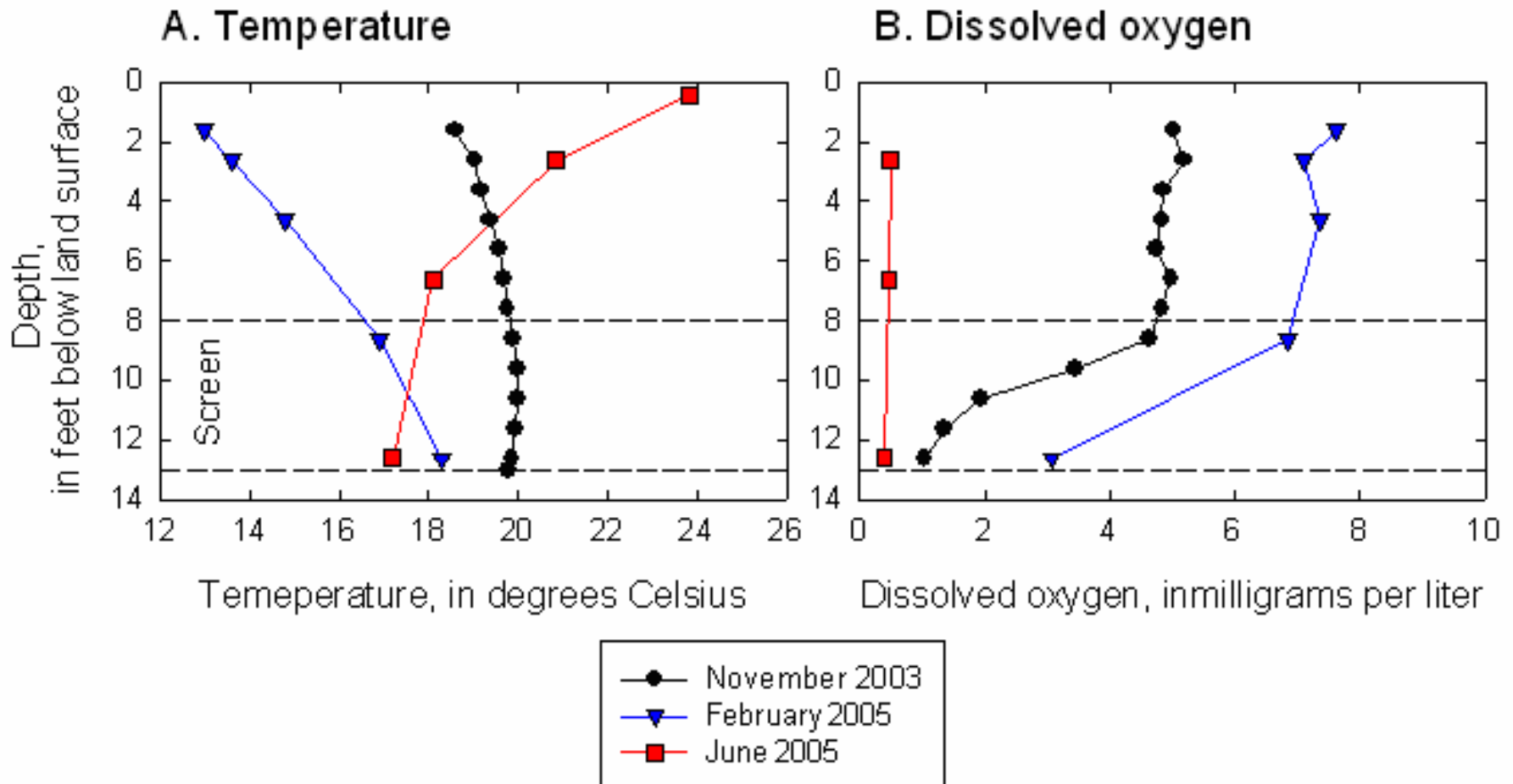
In-well convection has been recognized for some time

- Oil industry (Diment, 1967; Sammel, 1968)
 - It wasn't considered a monitoring-well problem because 3-casing-vol purge was a vigorous way to sample and overwhelmed the effect.
- Closed PVC pipe (Martin-Hayden, 2001)
 - Showed that convection can be vigorous in closed PVC pipes.

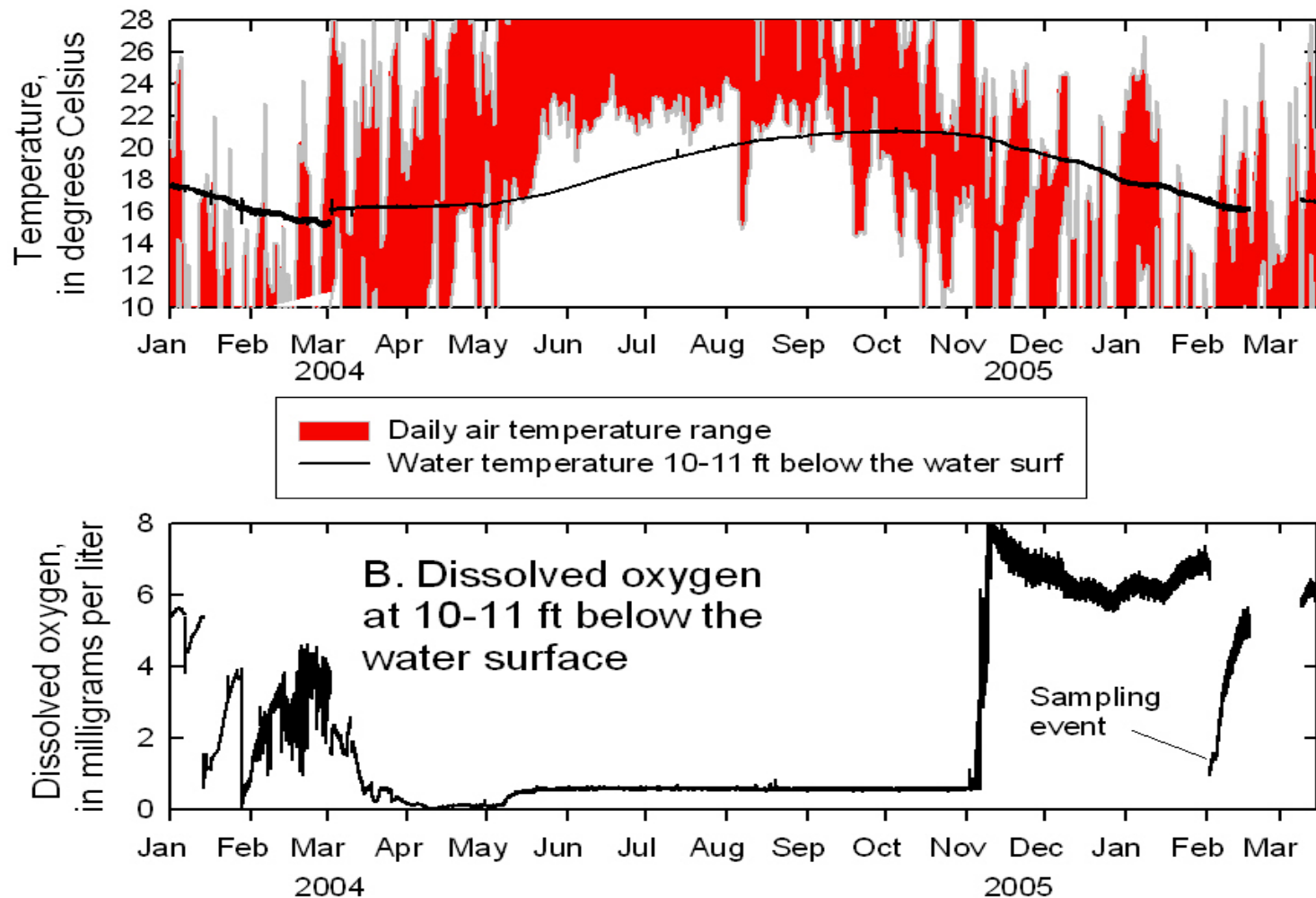
**Vroblesky, D.A., Casey, C.C., and Lowery, M.A.,
in press 2007, Influence of dissolved-oxygen
convection on well sampling: *Ground Water
Monitoring and Remediation*.**

- Showed convection takes place under field conditions.
- Examined some of the influences on convection.
- Showed that convection can have a profound influence on both passive and low-flow sampling.
- Showed that convection can easily be mitigated.

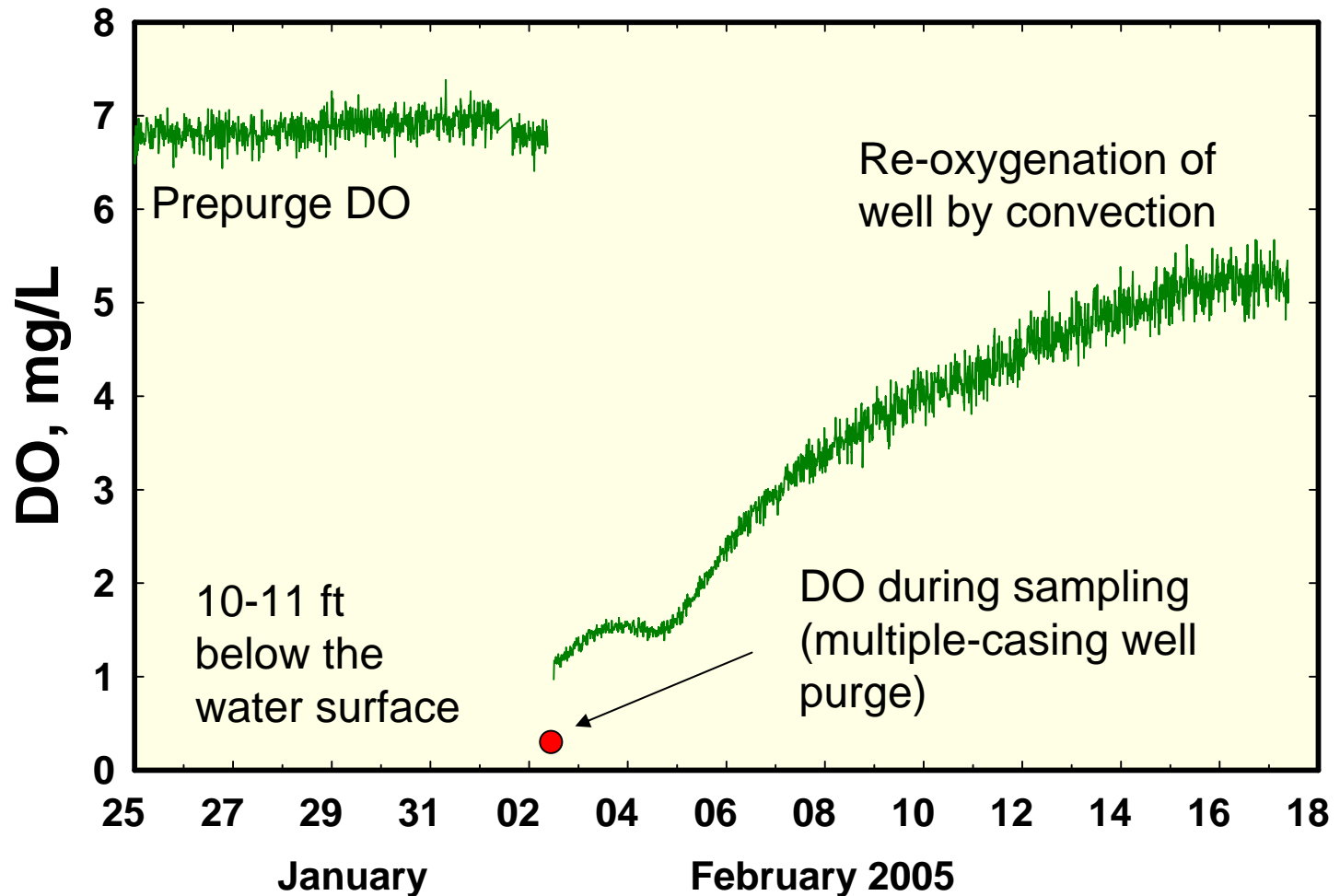
In-well convection can aerate wells



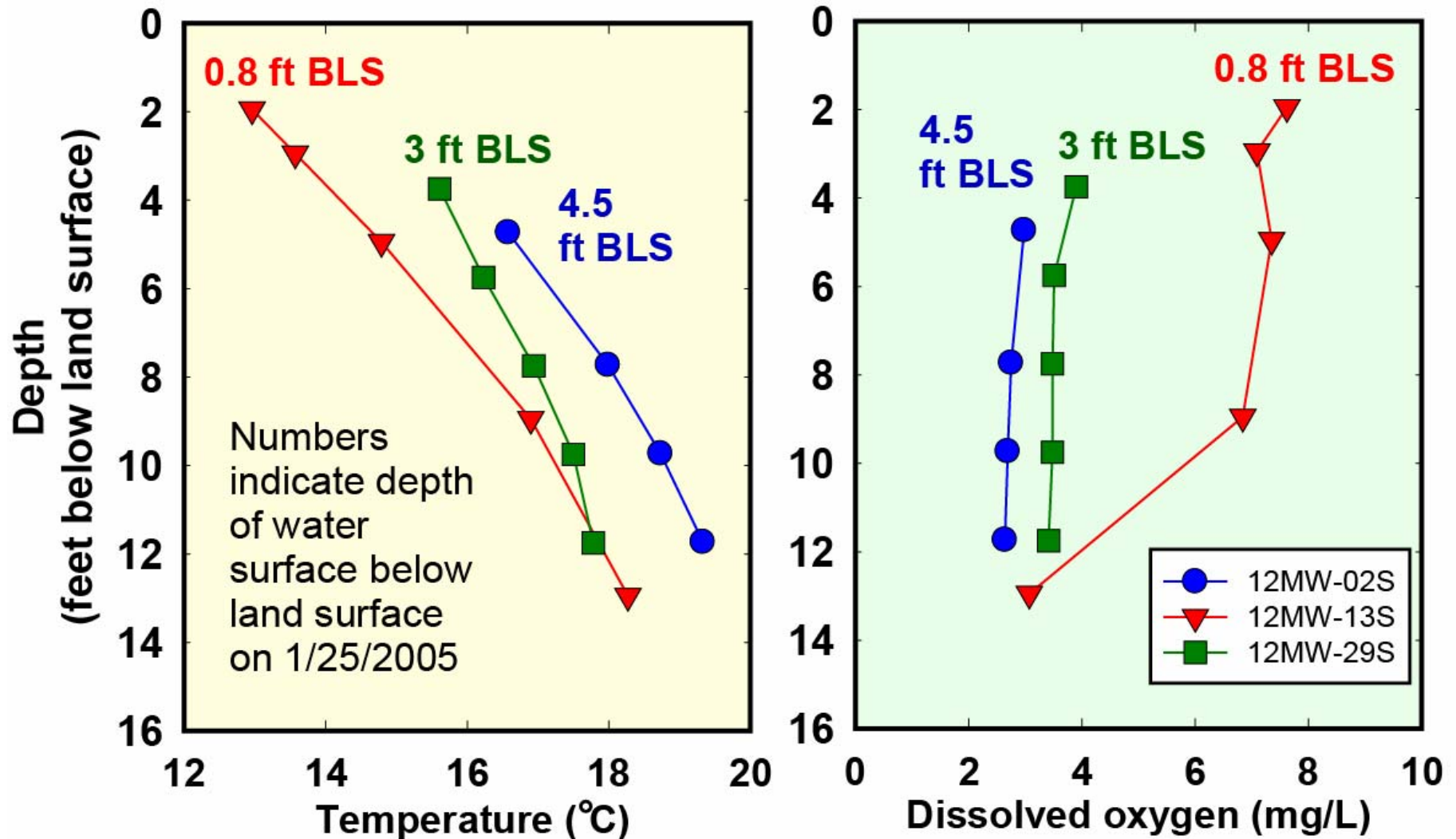
Decline and onset of convection



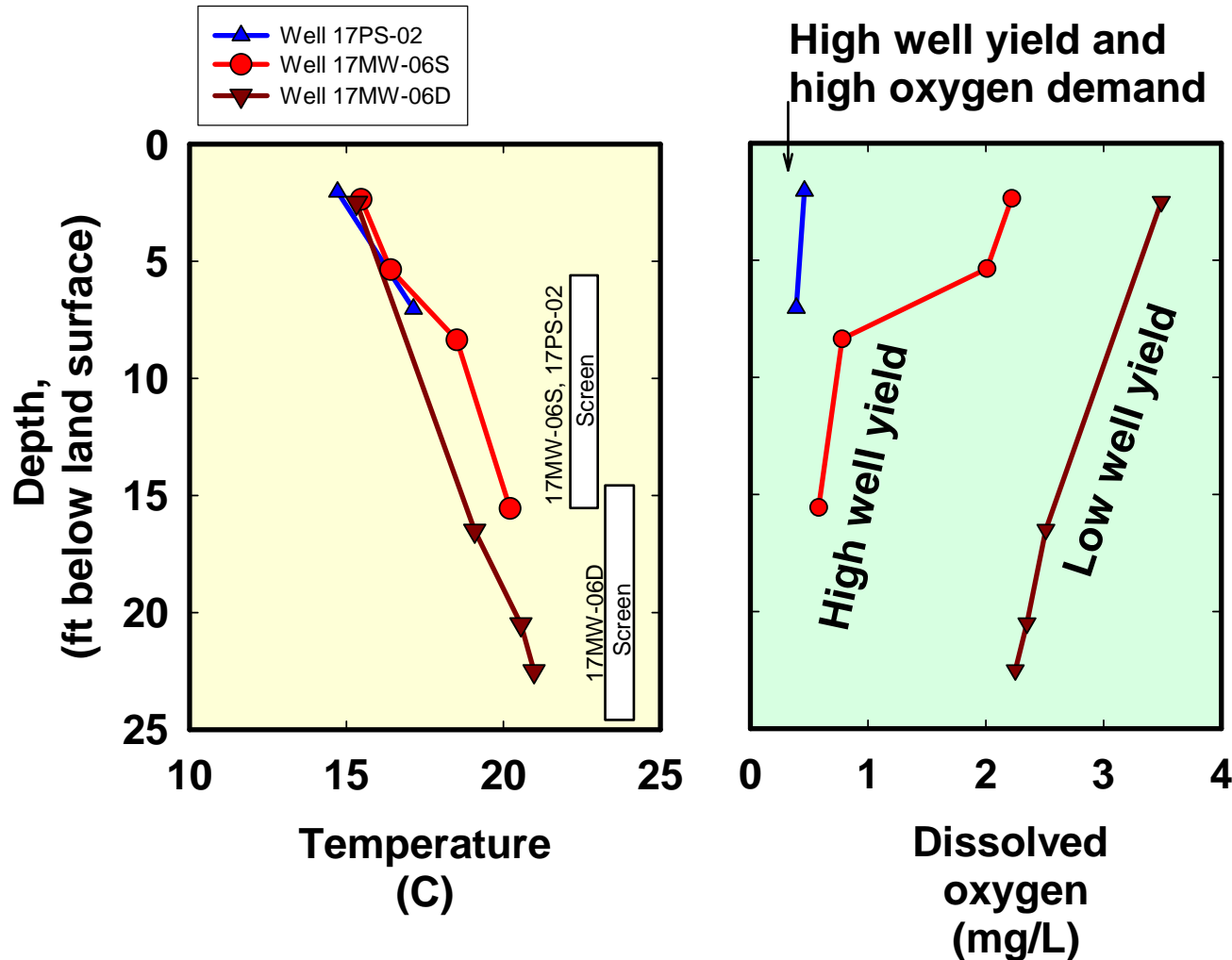
**After completely purging the aerobic water
from this well, convection rapidly
reoxygenated the water column
(2/2/05, NWS Charleston, SC, well 12MW-13S)**



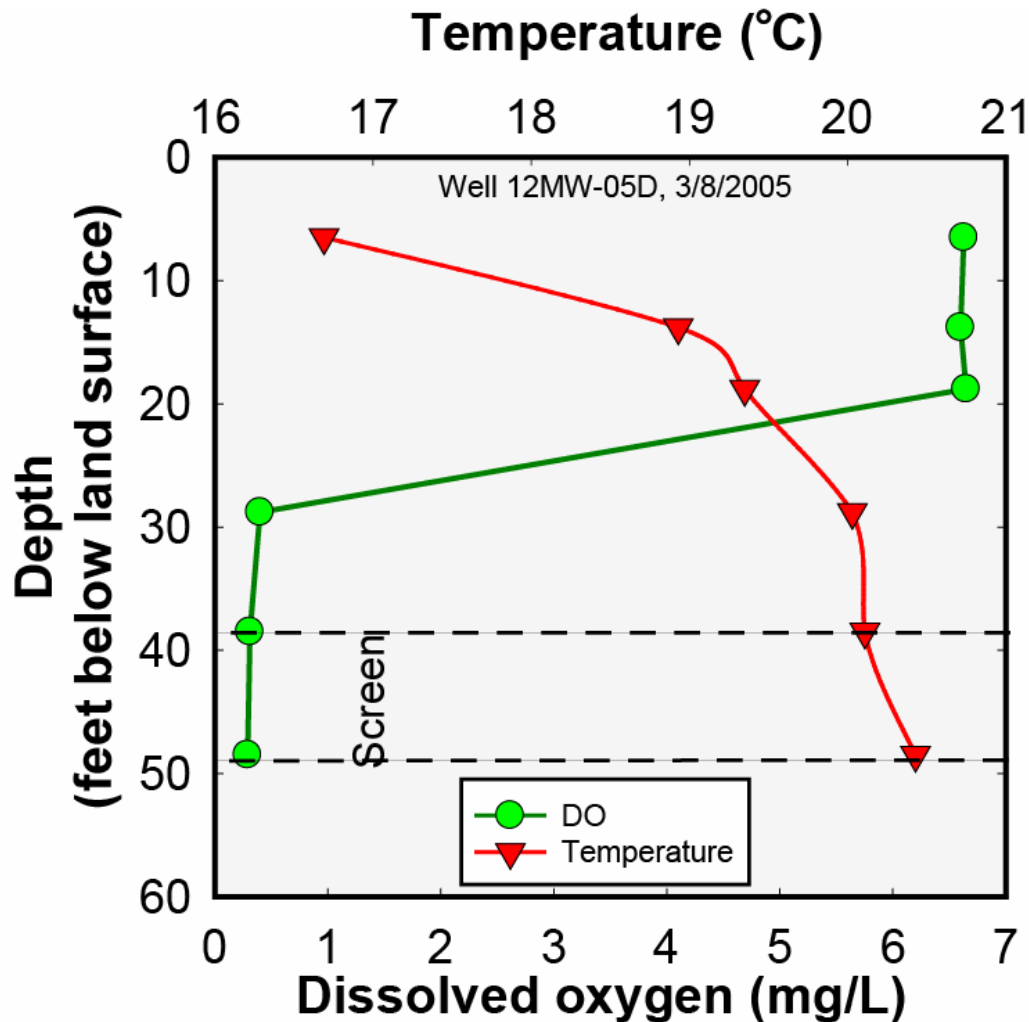
Strongest air-temperature influence is on the shallowest water surface



Exchange Through the Screen and Oxygen Demand Can Limit DO Convection



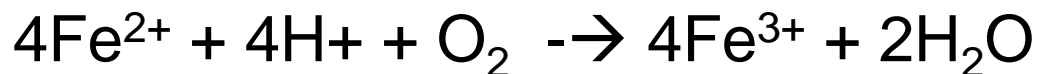
The Convection Cell May Not Extend to the Well Screen (3/8/05)



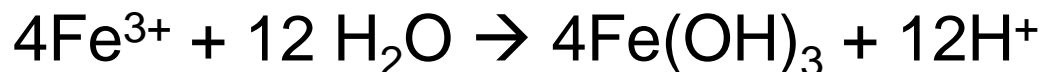
Influence of DO convection on well sampling

Impact on diffusion samplers for metals.

- A little bit of oxygen can cause dissolved iron to precipitate



- Which then can combine with water to make something microbes can use for iron reduction



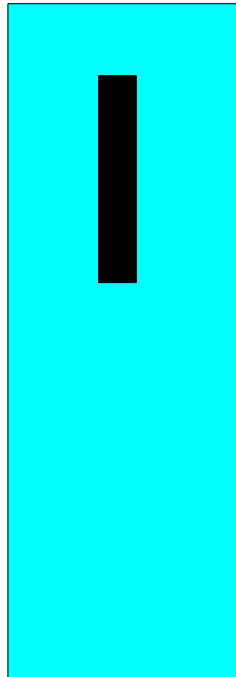
Degradation of CVOCs under different TEAPs (Bradley, 2003)

Reduct.	O2 Red.	Mn(IV) Red.	Fe(III) Red.	SO4 Red.	Methano- genesis
TCE	No	Fair	Good	Good	Excellent
DCE	Poor	Poor	Poor	Fair	Good
VC	Poor	Poor	Poor	Fair	Fair

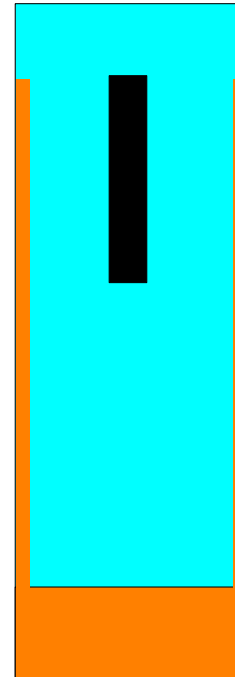
Oxidation	O2 Red.	Mn(IV) Red.	Fe(III) Red.	SO4 Red.	Methano- genesis
TCE	A CoM	No	No	No	No
DCE	Excellent	Good	Poor	Poor	Poor
VC	Excellent	Excellent	Excellent	Good	H. acid red.

DO convection can influence in-well metals concentrations

**No
DO convection:
High dissolved
iron**



**DO convection:
Low dissolved
iron**



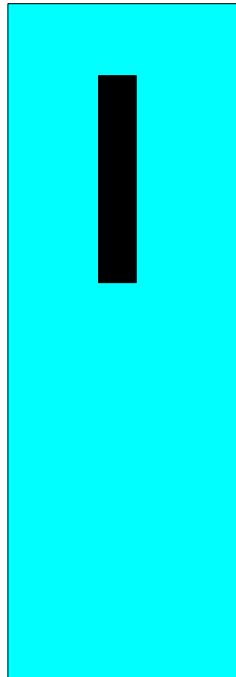
**Precipitated
iron**

DO convection can influence interpretation of microbial processes by both passive and pumped approaches

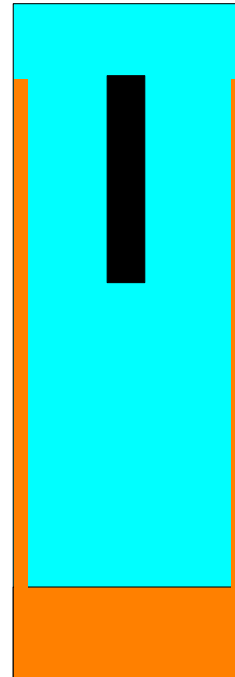
PASSIVE:

Because Fe-reducers can outcompete sulfate reducers and methanogens, the in-well TEAP in anaerobic aquifers may be oxygen reduction or iron reduction, regardless of the aquifer TEAP

**No
DO convection:
High dissolved
iron**



**DO convection:
Low dissolved
iron**



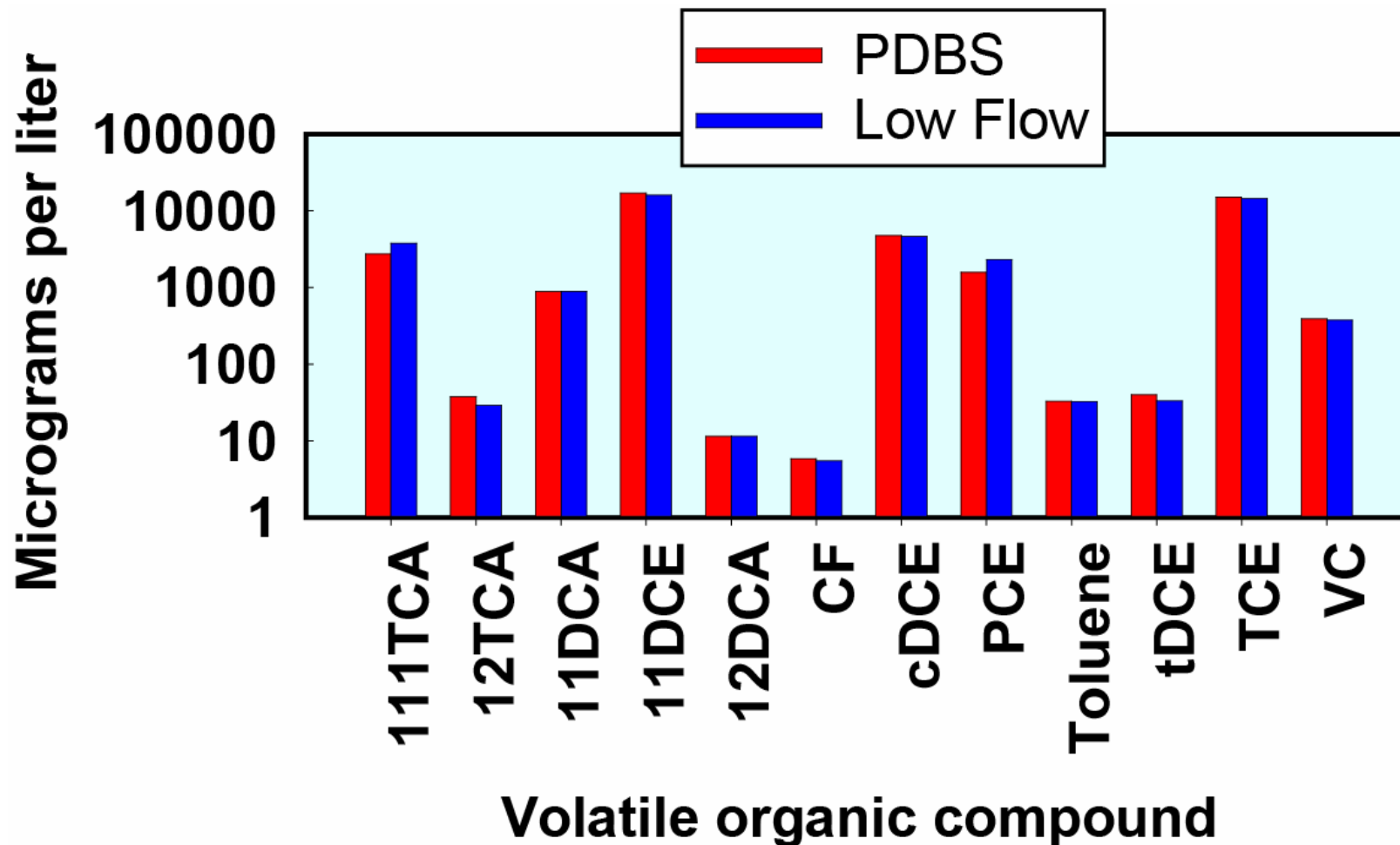
PUMPED:

The pumped particulates may primarily be precipitated iron, skewing the interpretation to iron reduction

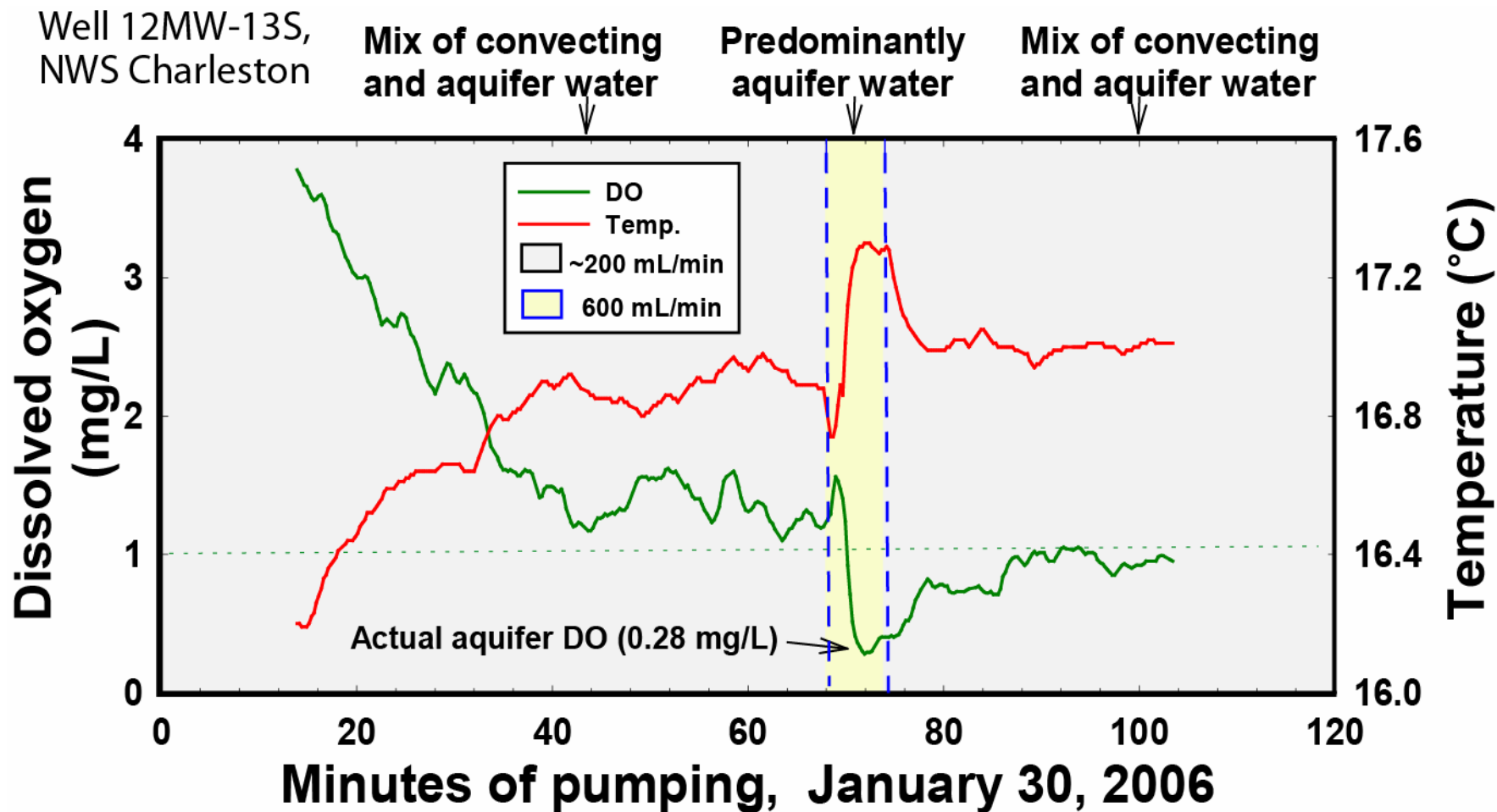
**Precipitated
iron**

Test of PDB sampler in a convecting well

(CH2MHILL Constructors, Inc., 2003)

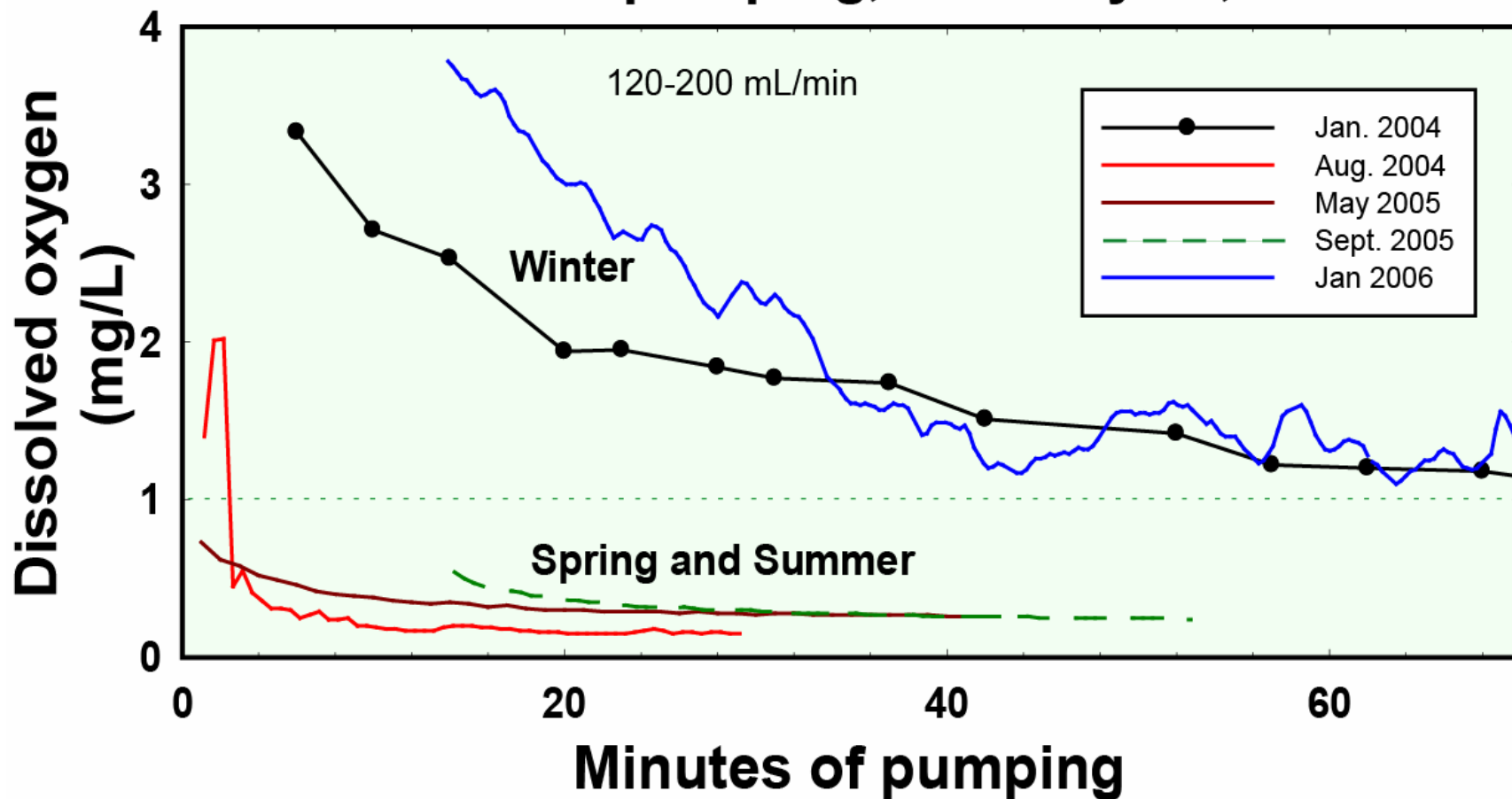


Influence of DO convection on low-flow sampling



Comparison of summer to winter low-flow stabilization times

Minutes of pumping, January 30, 2006



Differences in aerobic vs anaerobic degradation

- **Anaerobic degradation**

- TCE, PCE
- PCB
- Creosote, phenols
- Perchlorate
- nitrate

- **Aerobic degradation**

- Petroleum hydrocarbons
- Vinyl chloride
- *cis*-1,2-DCE
- MTBE
- Chlorobenzene

Thus, misinterpretation of anaerobic vs aerobic conditions can lead to selection of the wrong remedial action and inability to effectively monitor natural and engineered remediation

Degradation of CVOCs under different TEAPs (Bradley, 2003)

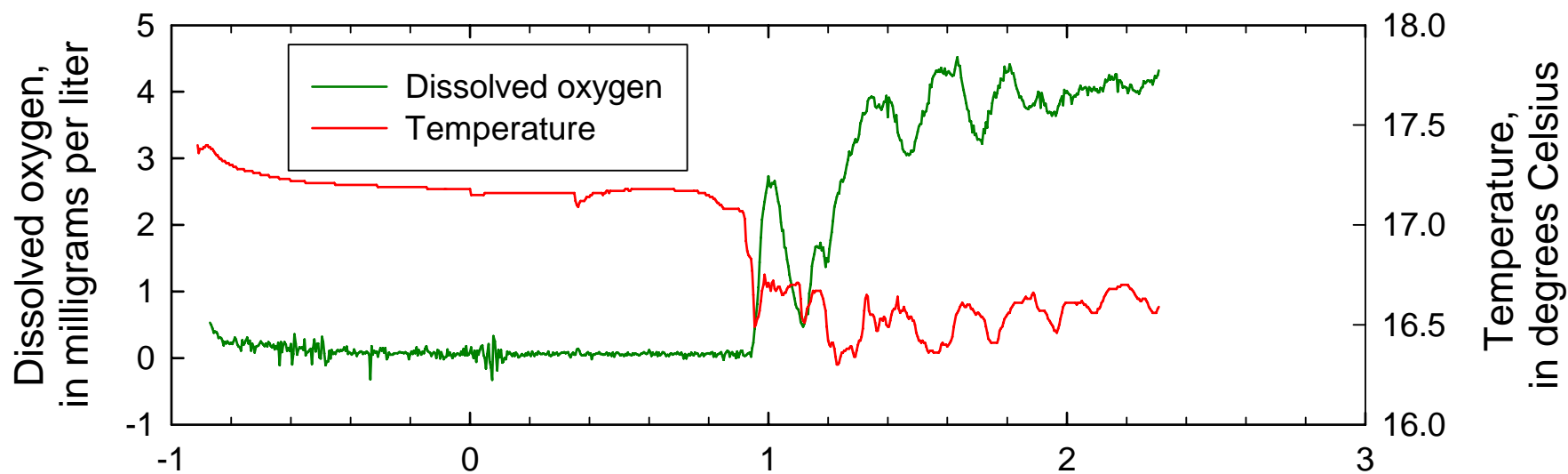
Reduct.	O2 Red.	Mn(IV) Red.	Fe(III) Red.	SO4 Red.	Methano- genesis
TCE	No	Fair	Good	Good	Excellent
DCE	Poor	Poor	Poor	Fair	Good
VC	Poor	Poor	Poor	Fair	Fair

Oxidation	O2 Red.	Mn(IV) Red.	Fe(III) Red.	SO4 Red.	Methano- genesis
TCE	A CoM	No	No	No	No
DCE	Excellent	Good	Poor	Poor	Poor
VC	Excellent	Excellent	Excellent	Good	H. acid red.

Simple mitigation of DO convection

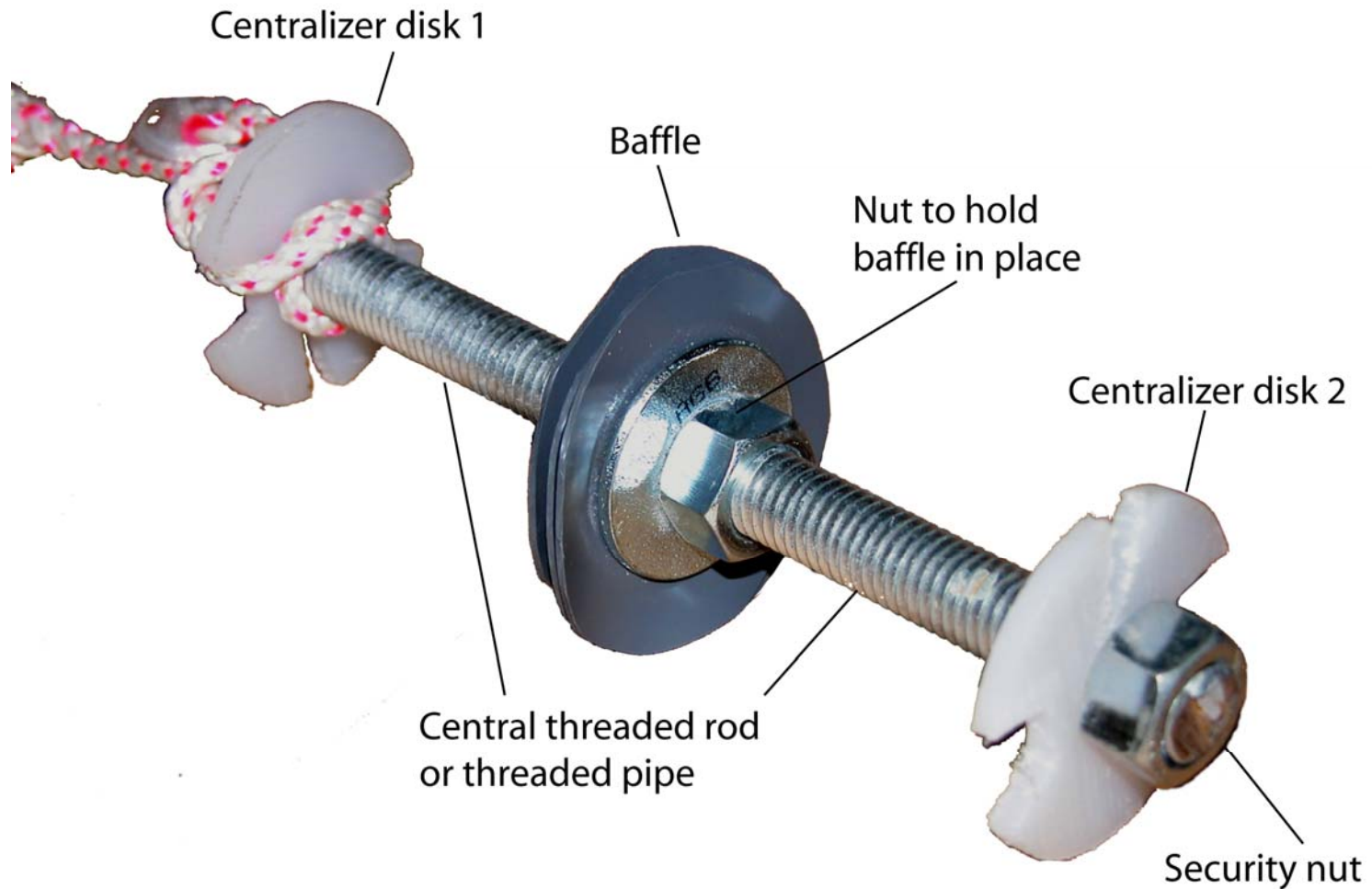
Convection in a well initiated by adding deionized ice in the summer

Sensors 13 ft below water surface

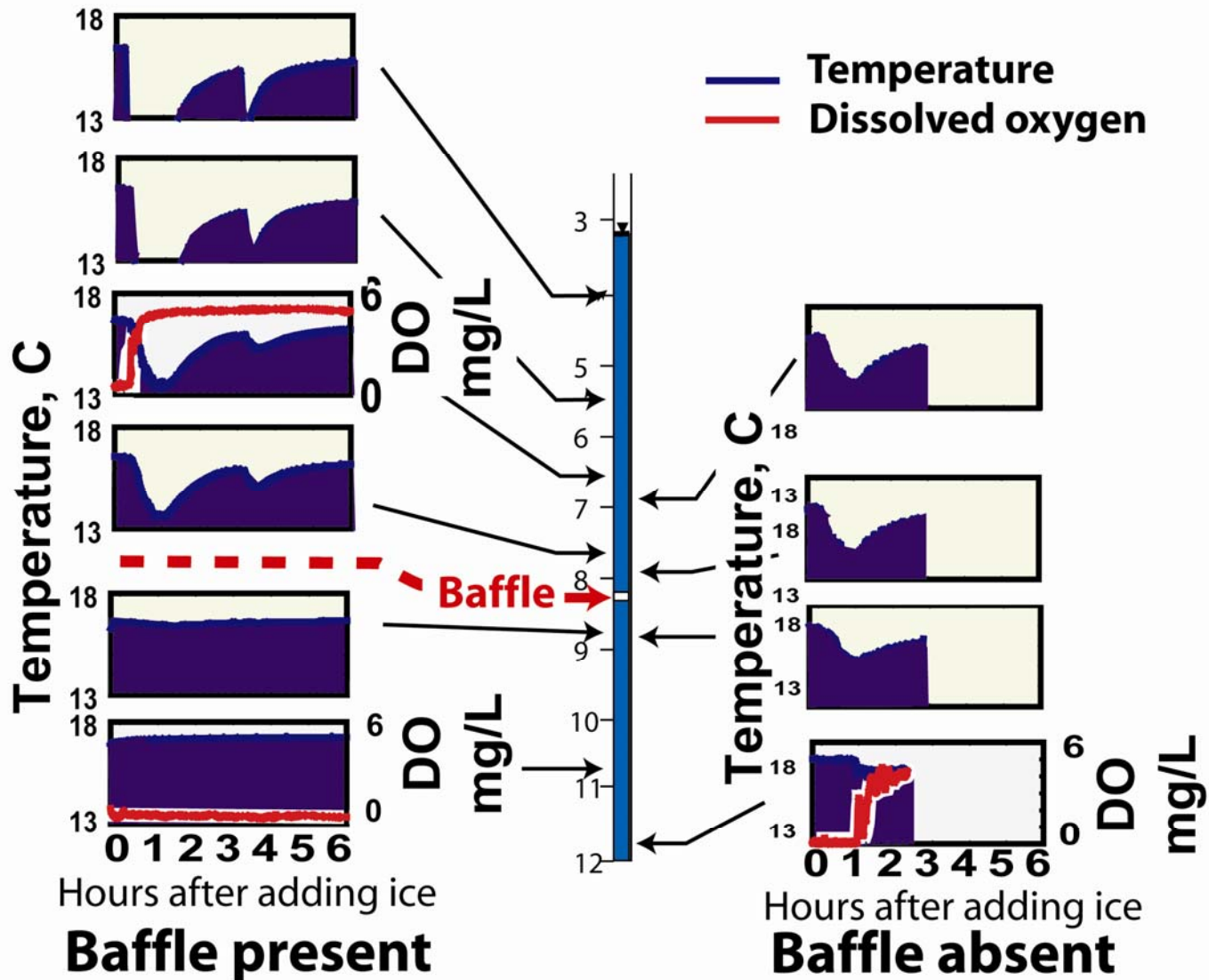


Hours before (-) and after (+) aerating the upper 3 feet and adding ice

Simple baffle



Deionized-ice test with well baffles



Summary (1 of 4)

- In-well convection can initiate when the upper part of the water column in the well becomes cooler than the deeper part.
- This is a winter phenomenon.
- In SC, convection took place from about early November to late March.
- Winter convection can aerate wells.
- Convection can vigorously mix well water.

Summary (2 of 4)

- Passive sampling in boreholes with no flow-limiting devices.
 - Can produce inaccurately low metals concentrations and inaccurately high DO concentrations
 - Can result in misleading microbial interpretations (in-well microcosms, passive samplers for redox indicators).
 - Did not see detrimental effect on use of PDB sampler for VOCs in the one tested well where convection was known to be taking place.

Summary (3 of 4)

- **Low-Flow Sampling. Convection can result in:**
 - Mixing of well-bore water with pumped aquifer water, potentially leading to solute concentrations not representative of the aquifer,
 - False indications of redox conditions in a well screened in an anerobic aquifer,
 - An increase low-flow equilibration times and false stabilization of indicator parameters during low-flow sampling,
 - False indication of microbial processes (for example, analysis of MBTs based on well sediment or colloids).
- **This is important because the misinterpretation of data can lead to an inappropriate remediation decision and an inability to accurately assess the remediation.**

Summary (4 of 4)

- Convection can easily and inexpensively be mitigated by in-well flow-limiting devices.
- The devices range from simple baffle systems to packer systems.